Materials Properties Handbook: Titanium Alloys

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Ti-6Al-4V

Ti64, 6Al-4V, 6-4
UNS Number: R56400 (normal interstitial grade); R56401 (extra-low interstitial grade); R56402 (filler metal)

Introduction

Ti-6Al-4V presently is the most widely used titanium alloy, accounting for more than 50% of all titanium tonnage in the world. To date, no other titanium alloy threatens its dominant position. The aerospace industry accounts for more than 80% of this usage. The next largest application of Ti-6Al-4V is medical prostheses, which accounts for 3% of the market. The automotive, marine, and chemical industries also use small amounts of Ti-6Al-4V (see the section "Applications" in this introduction).

Chemistry

Effects of Impurities and Alloying. Ti-6Al-4V is produced in a number of formulations. Depending on the application, the oxygen content may vary from 0.08 to more than 0.2% (by weight), the nitrogen content may be adjusted up to 0.05%, the aluminum content may reach 6.75%, and the vanadium content may reach 4.5%. The higher the content of these elements, particularly oxygen and nitrogen, the higher the strength. Conversely, lower additions of oxygen, nitrogen, and aluminum will improve the ductility, fracture toughness, stress-corrosion resistance, and resistance against crack growth.

ELI Grade. Ti-6Al-4V is available in ELI (extra-low interstitial) grades with high damage-tolerance properties, especially at cryogenic temperatures. The principal compositional characteristics are low oxygen and iron contents.

Ti-6Al-4V-Pd is a grade that has palladium additions (about 0.2 wt% Pd) for enhanced corrosion resistance. Sumitomo Titanium has produced this grade.

Product Forms

Ti-6Al-4V is available in wrought, cast, and powder metallurgy (P/M) forms, with wrought products accounting for more than 95% of the market. The properties of these various product forms will vary depending on their interstitial contents and thermal-mechanical processing. Processing methods and characteristics of Ti-6Al-4V are discussed in a separate section entitled "Processing."

Wrought Product Forms. Ti-6Al-4V is available in a wide range of wrought product forms (see Table).

The aircraft industry uses all wrought product forms. Forgings are used to fabricate various attachment fittings, and sheet and plate are used to fabricate numerous clips, brackets, skins, bulkheads, etc. Extrusions are not used extensively, but are used for parts such as wing chords and other parts with long, constant cross-sections. Wire is used to produce the numerous fasteners found on wings. Ti-6Al-4V tubing has been used for components such as torque tubes. In missile and space applications, Ti-6Al-4V has been used for rocket engine and motor cases, pressure vessels, wings, and generally in applications where weight is critical.

Castings. Ti-6Al-4V of the same chemistry as for wrought materials has excellent casting characteristics. However, the high reactivity of titanium in the molten state requires suitable casting technology and has limited the number of titanium foundries. In general terms, the mechanical and fatigue properties of castings will be slightly lower

Ti-6Al-4V: Wrought products

Product	Size and weight ranges	Price comparison(a)
Ingot	3200 to 13,600 kg (7000 to 30,000 lb)	...
Billet	Normally 100 mm (4 in.) diam to about 355 mm (14 in.) diam or square. Billets up to 5000 lb have been sold, but this is not necessarily the upper limit.	...
Bar	Cross-sections up to 0.4 × 0.4 m (16 × 16 in.)	...
Die forging	From <0.5 kg to >1300 kg (<1 lb to >3000 lb)	Ti, $30/lb; Al, $10/lb; stainless steel, $8/lb
Plate	Typical dimensions: Thickness: 5 to 75 mm (0.1875 to 3 in.); Width: 915 and 1220 mm (36 and 48 in.); Length: 1.8, 2.4, and 3 m (72, 96, and 120 in.)	...
Sheet	Typical dimensions: Thickness: 0.4 to 4.75 mm (0.016 to 0.187 in.); Width: 915 and 1220 mm (36 and 48 in.); Length: 1.8, 2.4, and 3 m (72, 96, and 120 in.)	Ti, $16/lb; stainless steel, $3/lb; Al, $2-4/lb; Inco 718, $10/lb
Tube	Specialty item	...
Forged block	Available in a wide range of sizes, with maximum size related to ingot size and the amount of work that can be imparted to the forged block	Ti, $8/lb; stainless steel and Al, $2.50-3/lb
Extrusion	From circle sizes of about 25 to 760 mm (1 to 30 in.) diam. Minimum thickness of about 3 mm (1/8 in.) for small circle sizes, and about 13 mm (1/2 in.) for large circle sizes	Ti, $13-15 lb; 300 series stainless steel, $3-4/lb; 15-5PH, $4-5/lb; 13-8PH, $9-12/lb; Al, $2-4/lb
Wire	Typically manufactured in sizes ranging from 0.28 to 12.2 mm (0.011 to 0.480 in.) diam	1/4 in. wire: Ti, $26/lb; A283, $6/lb; stainless steel, $7.50/lb; 8740, $1/lb; Al 7075, $2.30/lb

(a) Due to its lower density, 1 lb of titanium is approximately 1.7 to 1.8 more material by volume than 1 lb of steel or nickel-base alloy.

applications in high-performance and racing cars where weight is critical, usually in reciprocating and rotating parts, such as valves, valve springs, connecting rods, and rocker arms. It also has been used for drive shafts and suspension springs. Cast Ti-6Al-4V also has had minor use in automotive applications.

Marine applications of wrought Ti-6Al-4V include armaments, sonar equipment, deep-submergence applications, hydrofoils, and capsules for telephone-cable repeater stations. Casting applications include water-jet inducers for hydrofoil propulsion and seawater ball valves for nuclear submarines.

P/M Applications. The BE method produces a product with less than full density that can be as strong as wrought material, but that generally has lower ductility, toughness, and fatigue strength. Process modifications can improve these latter properties, even making them comparable to wrought, but they increase costs.

The BE approach has found a niche for the production of near-net-shape components or of low-cost preforms for subsequent processing, such as forging. Applications include sidewinder missile housing, missile fins, connecting rods, turbine blade preforms, hex stock preforms for fittings, nuts, mirror hubs, and lens housings.

High cost has thus far limited potential applications of PA technology to, for the most part, the manufacture of critical aerospace components. A number of demonstration parts are now flying in the F-15 and the F-18 airplanes, but none is made on a production basis. The increased demand for titanium aluminides in higher-temperature applications is creating interest in PA technology of P/M titanium.

Ti-6Al-4V and equivalents: specifications and compositions

Specification	Designation	Description	Al	C	Fe	H	N	O	V	OT	Other
UNS	R56400	Weld Wir	5.5-6.75	0.1	0.4	0.015	0.05	0.2	3.5-4.5		bal Ti
UNS	R56401		6						4		bal Ti
UNS	R56402	Fill Met	5.5-6.75	0.04	0.15	0.005	0.012	0.1	3.5-4.5		bal Ti
Europe											
AECMA prEN2517	Ti-P63	Sh Strp Plt Bar Ann	5.5-6.75	0.08	0.3	0.01	0.05	0.2	3.5-4.5	0.4	bal Ti
AECMA prEN2530		Bar Ann	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN2531		Frg Ann	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN3310		Frg NHT	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN3311		Bar Ann	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN3312		Frg Ann	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN3313		Frg NHT	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN3314		Bar STA	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN3315		Frg STA	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN3352		Inv Cast Ann HIP	5.5-6.75	0.1 max	0.3 max	0.015 max	0.05 max	0.22 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN3353		Bar Wir STA	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN3354		Sh Ann	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN3355		Ext Ann	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN3456		Sh Strp Ann	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN3457		Frg NHT	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN3458		Bar Wir Ann	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN3464		Plt Ann	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
AECMA prEN3467		Remelt NHT	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	OE 0.1 max; bal Ti
France											
AIR 9183	T-A6V	Bar Rod Frg	5.5-7	0.08	0.25	0.012	0.07	0.2	3.5-4.5		bal Ti
AIR 9184	T-A6V	Blt	5.5-7	0.08 max	0.25 max	0.12 max	0.07 max	0.2 max	3.5-4.5		bal Ti
Germany											
DIN	3.7164	Sh Strp Plt Bar Frg Ann	5.5-6.75	0.08	0.3	0.0125-0.015	0.05	0.2	3.5-4.5	0.4	bal Ti
DIN	3.7264	Cast Ann	5.5-6.75	0.1	0.3	0.015	0.05	0.2	3.5-4.5	0.4	bal Ti
DIN 17850	3.7165	Plt Sh Strp Rod Wir Ann	5.5-6.75	0.08	0.3	0.015	0.05	0.2	3.5-4.5		bal Ti

(continued)

Ti-6Al-4V and equivalents: specifications and compositions (continued)

Specification	Designation	Description	Al	C	Fe	H	N	O	V	OT	Other
DIN 17851	3.7165	Sh Plt Strp Rod Wir Ann	5.5-6.75	0.08	0.3	0.015	0.05	0.2	3.5-4.5		bal Ti
DIN 17860	3.7615	Sh Strp	5.5-6.75	0.2 max	0.3 max	0.015 max	0.05 max		3.5-4.5		bal Ti
DIN 17862	3.7615	Rod	5.5-6.75	0.08 max	0.3 max	0.015 max	0.05 max	0.2 max	3.5-4.5		bal Ti
DIN 17864	3.7615	Frg	5.5-6.75	0.08 max	0.3 max	0.015 max	0.05 max	0.2 max	3.5-4.5		bal Ti
Russia											
GOST 19807-74	VT6S	Sh Plt Strp Foil Rod Ann	5.3-6.8	0.08	0.25	0.007	0.05	0.015	3.5-4.5	0.3	Zr 0.3; Si 0.15; bal Ti
OST 1.90000-70	VT6	Sh Plt Strp Foil Rod Frg Ann	5.5-7	0.1	0.3	0.015	0.05	0.2	4.2-6	0.3	Si 0.15; bal Ti
OST 1.90060-72	VT6L	Cast	5-6.5	0.1	0.3	0.015	0.05	0.15	3.5-4.5	0.3	Zr 0.3; Si 0.15; W 0.2; bal Ti
Spain											
UNE 38-723	L-7301	Sh Plt Strp Bar Ex Ann	5.5-6.75	0.1	0.3	0.125	0.05	0.2	3.5-4.5	0.4	bal Ti
UNE 38-723	L-7301	Sh Plt Strp Bar Ex HT	5.5-6.75	0.1	0.3	0.125	0.05	0.2	3.5-4.5	0.4	bal Ti
UK											
BS 2TA.10		Sh Strp HT	5.5-6.75		0.3	0.01					V 3.5-4.5; Ti 88.18 max; O+N=0.25
BS 2TA.11		Bar	5.5-6.75		0.3	0.01	0.05	0.2			V 3.5-4.5; Ti 88.18 max;
BS 2TA.12		Frg	5.5-6.75		0.3	0.01	0.05	0.2	3.5-4.5		Ti 88.19 max;
BS 2TA.13		Frg HT	5.5-6.75		0.3	0.01		0.2	3.5-4.5		Ti 88.18 max;
BS 2TA.28		Wir Frg HT Quen	5.5-6.75		0.3	0.01	0.05	0.2	3-5		Ti 88.19 max;
BS 3531 Part 2		Srg Imp	5.5-6.75	0.08 max	0.3 max	0.015 max		0.2 max	3.5-4.5		bal Ti
BS TA.56		Plt to 100 mm HT	5.5-6.75		0.3				3.5-4.5		Ti 88.2 max; O+N=0.25
BS TA.59		Sh Strp	5.5-6.75	0.08 max	0.3 max	0.0125 max			3.5-4.5		N+O=0.25; bal Ti
DTD 5303		Bar Ann	5.5-6.75	0.2 max	0.3 max	0.0125 max	0.05 max		3.5-4.5		bal Ti
DTD 5313		Frg Ann	5.5-6.75		0.3 max	0.01 max	0.05 max	0.2 max	3.5-4.5		bal Ti
DTD 5323		Frg Ann	5.5-6.75		0.3 max	0.015 max	0.05 max	0.2 max	3.5-4.5		bal Ti
DTD 5363		Cast	5.5-6.75		0.3 max	0.15 max	0.05 max	0.25 max	3.5-4.5		N+O=0.27; bal Ti
USA											
AMS 4905A		ELI Plt	5.6-6.3	0.05 max	0.25 max	0.0125 max	0.03 max	0.12 max	3.6-4.4	0.4 max	Y 0.005 max; OE 0.1 max; bal Fe
AMS 4905A		Plt Beta Ann	5.6-6.3	0.05	0.25	0.0125	0.03	0.12	3.6-4.4	0.4	Y 0.005; bal Ti
AMS 4906		Sh Strp	5.5-6.75	0.08 max	0.3 max	0.0125 max	0.05 max	0.2 max	3.5-4.5	0.4 max	Y 0.005 max; bal Ti
AMS 4907D		ELI Sh Strp Plt Ann	5.5-6.5	0.08	0.25	0.0125	0.05	0.13	3.5-4.5	0.3	Y 0.005; bal Ti
AMS 4911F		Sh Strp Plt Ann	5.5-6.75	0.08	0.3	0.015	0.05	0.2	3.5-4.5	0.4	bal Ti
AMS 4920		Frg Ann	5.5-6.75	0.1	0.3	0.0125	0.05	0.2	3.5-4.5	0.4	Y 0.005; bal Ti
AMS 4928K		Bar Wir Frg Bil Rng Ann	5.5-6.75	0.1	0.3	0.0125	0.05	0.2	3.5-4.5	0.4	bal Ti
AMS 4930C		ELI Bar Wir Frg Bil Rng Ann	5.5-6.5	0.08	0.25	0.0125	0.05	0.13	3.5-4.5	0.4	Y 0.005; bal Ti
AMS 4931		ELI Bar Frg Bil Rng	5.5-6.5	0.08	0.25	0.0125	0.03	0.13	3.5-4.5	0.4	Y 0.005; bal Ti
AMS 4934A		Ex Rng STA	5.5-6.75	0.1	0.3	0.0125	0.05	0.2	3.5-4.5	0.4	Y 0.005; bal Ti
AMS 4935E		Ex Rng Ann	5.5-6.75	0.1	0.3	0.0125	0.05	0.2	3.5-4.5	0.4	Y 0.005; bal Ti
AMS 4954D		Fill met gas-met/W-arc weld	5.5-6.75	0.05	0.3	0.015	0.03	0.18	3.5-4.5	0.4	Y 0.005; bal Ti
AMS 4956B		ELI Fill Met Wir	5.5-6.75	0.03	0.15	0.005	0.012	0.08	3.5-4.5	0.1	Y 0.005; bal Ti
AMS 4965E		Bar Frg Rng STA/Mach Press ves	5.5-6.75	0.08	0.3	0.0125	0.05	0.2	3.5-4.5	0.4	Y 0.005; bal Ti
AMS 4967F		Bar Frg Rng Mach/STA Press ves	5.5-6.75	0.08	0.3	0.0125	0.05	0.2	3.5-4.5	0.4	Y 0.005; bal Ti
AMS 4985A		Cast Ann	5.5-6.75	0.1	0.3	0.015	0.05	0.2	3.5-4.5	0.4	Y 0.005; bal Ti
AMS 4991A		Cast Ann	5.5-6.75	0.1	0.3	0.015	0.05	0.2	3.5-4.5	0.4	Y 0.005; bal Ti
AMS 4993A		Powd Sint Nuts	5.5-6.75	0.1	0.3	0.01	0.05	0.3	3.5-4.5	0.4	Si 0.05; Na 0.15; Cl 0.15; bal Ti

(continued)

Ti-6Al-4V and equivalents: specifications and compositions (continued)

Specification	Designation	Description	Al	C	Fe	H	N	O	V	OT	Other
AMS 4996		Bill Powd Ann	5.5-6.75	0.1	0.3	0.0125	0.04	0.13-0.19	3.5-4.5	0.2	Mo 0.1 max; Sn 0.1 max; Zr 0.1 max; Mn 0.1 max; Cu 0.1 max; Y 0.001; bal Ti
AMS 4996		ELI Bil	5.5-6.75	0.1 max	0.3 max	0.0125 max	0.04 max	0.13-0.19	3.5-4.5	0.2 max	Y 0.001 max; OE 0.1 max; bal Ti
AMS 4998		ELI Powd	5.5-6.75	0.1 max	0.3 max	0.0125 max	0.04 max	0.13-0.19		0.2 max	Y 0.001 max; OE 0.1 max; bal Ti
AMS 4998		Powd	5.5-6.75	0.1	0.3	0.012	0.04	0.13-0.18	3.5-4.5	0.2	Mo 0.1 max; Sn 0.1 max; Zr 0.1 max; Mn 0.1 max; Cu 0.1 max; Y 0.001; bal Ti
ASTM B 265	Grade 5	Sh Strp Plt Ann	5.5-6.75	0.1	0.4	0.015	0.05	0.2	3.5-4.5	0.4	bal Ti
ASTM B 348	Grade 5	Bar Bil Ann	5.5-6.75	0.1	0.4	0.0125	0.05	0.2	3.5-4.5	0.4	bal Ti
ASTM B 367	Grade C-5	Cast	5.5-6.75	0.1	0.4	0.015	0.05	0.25	3.5-4.5	0.4	bal Ti
ASTM B 381	Grade F-5	Frg Ann	5.5-6.75	0.1	0.4	0.0125	0.05	0.2	3.5-4.5	0.4	bal Ti
ASTM F136		ELI Wrought Ann for Surg Imp	5.5-6.5	0.08	0.25	0.012	0.05	0.13	3.5-4.5		bal Ti
ASTM F467-84	Grade 5	Blt Scr Std	5.5-6.75	0.1 max	0.4 max	0.0125 max	0.05 max	0.2 max	3.5-4.5		bal Ti
ASTM F468-84		Blt Scr Std	5.5-6.75	0.1 max	0.4 max	0.0125 max	0.05 max	0.2 max	3.5-4.5		bal Ti
AWS A5.16-70	ERTi-6Al-4V	Weld fill met	5.5-6.75	0.05	0.25	0.008	0.02	0.15	3.5-4.5		bal Ti
AWS A5.16-70	ERTi-6Al-4V-1	ELI Fill Met Wir Rod	5.5-6.75	0.04	0.15	0.005	0.012	0.1	3.5-4.5		bal Ti
MIL A-46077D		Weld armor plt Ann	5.5-6.5	0.04	0.25	0.0125	0.02	0.14	3.5-4.5	0.4	bal Ti
MIL F-83142A	Comp 6	Frg Ann	5.5-6.75	0.08	0.3	0.015	0.05	0.2	3.5-4.5	0.4	bal Ti
MIL F-83142A	Comp 6	Frg HT	5.5-6.75	0.08	0.3	0.015	0.05	0.2	3.5-4.5	0.4	bal Ti
MIL F-83142A	Comp 7	ELI Frg Ann	5.5-6.5	0.08	0.2-0.25	0.0125	0.05	0.13	3.5-4.5	0.3	bal Ti
MIL F-83142A	Comp 7	ELI Frg HT	5.5-6.5	0.08	0.25	0.0125	0.05	0.13	3.5-4.5	0.3	bal Ti
MIL T-81556A	Code AB-1	Ex Bar Shp Ann	5.5-6.75	0.08	0.3	0.0125	0.05	0.2	3.5-4.5	0.4	bal Ti
MIL T-81556A	Code AB-1	EX Bar Shp STA	5.5-6.75	0.08	0.3	0.0125	0.05	0.2	3.5-4.5	0.4	bal Ti
MIL T-81556A	Code AB-2	ELI Ext Bar Ann	5.5-6.5	0.08	0.25	0.0125	0.05	0.13	3.5-4.5	0.3	bal Ti
MIL T-81915	Type III Comp A	Cast Ann	5.5-6.75	0.08	0.3	0.015	0.05	0.2	3.5-4.5	0.4	bal Ti
MIL T-9046J	Code AB-1	Sh Strp Plt Ann	5.5-6.75	0.08	0.3	0.0125	0.05	0.2	3.5-4.5	0.4	bal Ti
MIL T-9046J	Code AB-1	Sh Strp Plt STA	5.5-6.75	0.08	0.3	0.0125	0.05	0.2	3.5-4.5	0.4	bal Ti
MIL T-9046J	Code AB-2	ELI Sh Strp Plt Ann	5.5-6.5	0.08	0.25	0.0125	0.05	0.13	3.5-4.5		bal Ti
MIL T-9047G		Bar Bil STA	5.5-6.75	0.08	0.3	0.015	0.05	0.2	3.5-4.5	0.4	Y 0.005; bal Ti
MIL T-9047G		ELI Bar Bil Ann	5.5-6.5	0.08	0.25	0.0125	0.05	0.13	3.5-4.5	0.3	Y 0.005; bal Ti
MIL T-9047G	MIL-T-9047G	Bar Bil Ann	5.5-6.75	0.08	0.3	0.015	0.05	0.2	3.5-4.5	0.4	Y 0.005; bal Ti
SAE J467		ELI	6.18	0.023	0.22	0.008	0.026	0.097			bal Ti

Ti-6Al-4V commercial equivalents: compositions

Specification	Designation	Description	Al	C	Fe	H	N	O	V	OT	Other
France											
Ugine	UTA6V	Sh Strp Plt Bar Frg Ann	5.5-6.75	0.08	0.3	0.015	0.07	0.2	3.5-4.5		bal Ti
Ugine	UTA6V	Sh Strp Plt Bar Frg STA	5.5-6.75	0.08	0.3	0.015	0.07	0.2	3.5-4.5		bal Ti
Germany											
DeutscheT.	LT 31	Ann	5.5-6.5	0.08	0.25	0.013	0.07	0.2	3.5-4.5		bal Ti
Fuchs	TL64	Frg	6						4		bal Ti
Fuchs	TL64 ELI	ELI Frg	6						4		bal Ti
Thyssen	Contimet AlV 64	Plt Bar Frg Ann	5.5-6.75	0.1	0.3	0.015	0.05	0.2	3.5-4.5		bal Ti
Thyssen	Contimet AlV 64	Plt Bar Frg STA	5.5-6.75	0.1	0.3	0.015	0.05	0.2	3.5-4.5		bal Ti
Thyssen	Contimet AlV 64 ELI	ELI Plt Bar Frg Pip Ann	5.5-6.75	0.06	0.15	0.013	0.05	0.13	3.5-4.5		bal Ti
Japan											
Daido	DAT 5	Rod Bar Rng Frg Ann	5.5-6.75	0.1	0.3	0.015		0.05	3.5-4.5		bal Ti
Daido	DAT 5	Rod Bar Rng Frg STA	5.5-6.75	0.1	0.3	0.015	0.05	0.2	3.5-4.5		bal Ti
Daido	DT 5	Rod Bar Frg Rng STA	5.5-6.75	0.1	0.3	0.015	0.05	0.2	3.5-4.5		bal Ti

(continued)

Ti-11.5Mo-6Zr-4.5Sn

Common Name: Beta III
UNS No. R58030

Beta III was developed in the 1960s by Crucible Steel. This alloy was intended to supplement Ti-13V-11Cr-3Al. It has excellent cold workability, heat treatability and mechanical properties, but it is very difficult to melt without molybdenum segregation. Crucible stopped making Beta III when they decreased their participation in the titanium market.

Chemistry. The chemistry balance ultimately selected for Beta III (11.5 Mo, 6 Zr, 4.5 Sn wt%) is a solute-rich composition developed by a semi-empirical balancing of desired properties. Molybdenum is a strong beta stabilizing element completely soluble in beta titanium at elevated temperatures, and the nominal composition of Beta III contains enough of this element by itself to stabilize the beta phase to room temperature. Zirconium and tin, often called neutral stabilizing additions to titanium, augment the beta phase stabilization in the quantities used in the Beta III alloy. Both zirconium and tin strengthen the alpha and beta phases of titanium and are soluble in both phases. Molybdenum, zirconium, and tin were combined in the Beta III formulation in quantities which produce very sluggish beta-phase reaction kinetics.

At the same time, the amount of beta stabilizers was limited by cost and density considerations. Also, the uniformity of tensile ductility in the solution treated condition decreased with a more highly stabilized beta phase.

Density. 5.06 g/cm^3 (0.183 lb/in.^{3})

Product Forms. Limited availability at present in all mill product forms.

Applications. Aircraft fasteners, especially rivets, and sheet metal parts where cold formability and strength potential can be used to greatest advantage. Commercial applications have included springs and orthodontic appliances. Possible use in plate and forging applications where high strength, deep hardenability, and resistance to stress corrosion are required and somewhat lower ductility is acceptable.

Product Condition. Beta III is solution treated above and below the beta transus depending on the desired properties. Brief solution treatment above the transus is sometimes used when maximum cold formability or deep hardenability is sought, but from the mill the Beta III alloy is usually solution treated slightly below the transus temperature. Solution treatment of worked material below or at the beta transus preserves a high dislocation density, which in turn results in a fine alpha dispersion upon subsequent aging. This condition generally gives the best combination of strength and ductility. The microstructure of Beta III is equiaxed beta when solution annealed above the beta transus, while a mixture of equiaxed alpha in a beta matrix is present when solution annealing is performed in the $\alpha + \beta$ phase field.

Ti-11.5Mo-6Zr-4.5Sn (Beta III): Specifications and compositions

Specification	Designation	Description	Composition, wt% C	Fe	H	Mo	N	O	Sn	Zr	Other
UNS	R58030		0.1	0.35	0.02	10-13	0.05	0.18	3.75-5.25	4.5-7.5	
Spain											
UNE 38-730	L-7702	Sh Str Bar Frg Tube HT	0.1	0.35	0.02	10-13	0.05	0.18	3.75-5.25	4.5-7.5	OT 0.4; bal Ti
USA											
AMS 4980B		Bar Wir SHT	0.1	0.35	0.015	10-13	0.05	0.18	3.75-5.25	4.5-7.5	OT 0.4; Y 0.005; bal Ti
AMS 4980B		Bar Wir STA	0.1	0.35	0.015	10-13	0.05	0.18	3.75-5.25	4.5-7.5	OT 0.4; Y 0.005; bal Ti
ASTM B265	Grade 10	Sh Plt Str ST	0.1	0.35	0.02	10-13	0.05	0.18	3.75-5.25	4.5-7.5	OT 0.4; bal Ti
ASTM B337	Grade 10	Pip ST	0.1	0.35	0.02	10-13	0.05	0.18	3.75-5.25	4.5-7.5	OT 0.4; bal Ti
ASTM B338	Grade 10	Tube Heat Ex/Con SHT	0.1	0.35	0.02	10-13	0.05	0.18	3.75-5.25	4.5-7	OT 0.4; bal Ti
ASTM B348(10)-87		Bar	0.1 max	0.35 max	0.02 max	10-13	0.05 max	0.18 max	3.75-5.25	4.5-7.5	OT 0.4 max; OE 0.1 max; bal Ti
ASTM B348(10)-87		Bil	0.1 max	0.35 max	0.015 max	10-13	0.05 max	0.18 max	3.75-5.25	4.5-7.5	OT 0.4 max; OE 0.1 max; bal Ti
MIL F-83142A	Comp 13	Frg Ann	0.1	0.35	0.02	10-13	0.05	0.18	3.75-5.25	4.5-7.5	OT 0.4; bal Ti
MIL F-83142A	Comp 13	Frg HT	0.1	0.35	0.02	10-13	0.05	0.18	3.75-5.25	4.5-7.5	OT 0.4; bal Ti
MIL T-9046J	Code B-2	ST	0.1	0.35	0.02	10-13	0.05	0.18	3.75-5.25	4.5-7.5	OT 0.4; bal Ti
MIL T-9047G	Ti-4.5Sn-6Zr-11.5Mo	Bar Bil SHT	0.1	0.35	0.02	10-13	0.05	0.18	3.75-5.25	4.5-7.5	OT 0.4; Y 0.005; bal Ti

(a) Maximum unless a range is specified

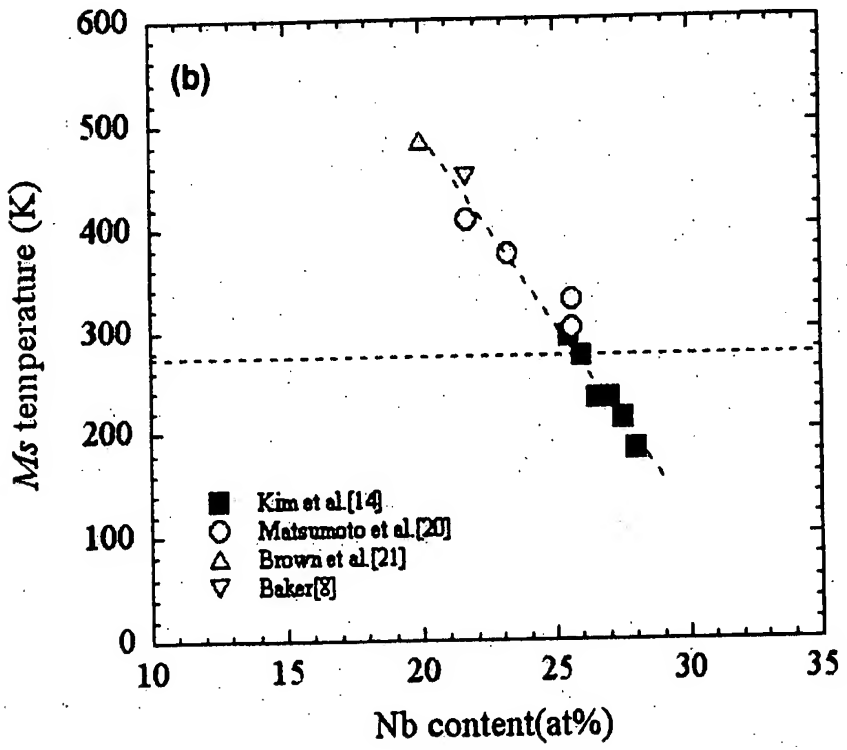

Fig.1 Relationship between Ms point and Nb content of Ti-Nb binary alloy
H.Y.Kim et al., *Acta Mater.* (2006)

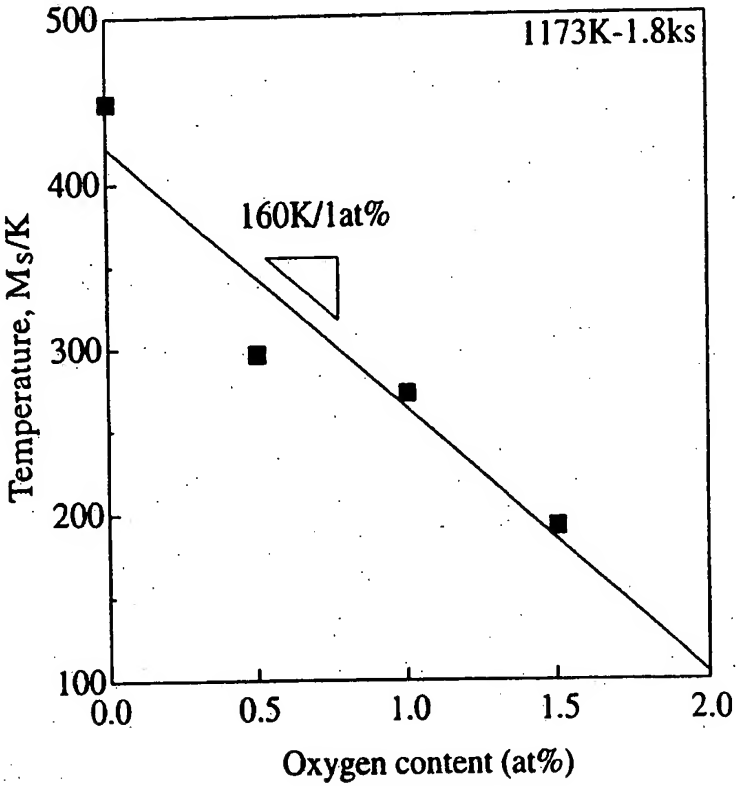

Fig. 2 Influence of O content on Ms point of Ti-22at%Nb alloy
J.I.Kim et al., *Mater. Trans.* (2005)